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METHOD AND DEVICE FOR DETERMINING A SPEED VARIABLE OF AT LEAST ONE DRIVEN WHEEL OF A MOTOR VEHICLE

Background Information

The present invention relates to a method and a device for determining a variable which describes the speed of at least one driven wheel of a motor vehicle. Using the method and the device, variables which describe the respective wheel speeds are ascertained for the remaining driven wheels of the motor vehicle. Furthermore, a variable is determined which describes the output rpm of a transmission of the motor vehicle.

The invention also relates to a control unit for a traction control system or a vehicle-dynamics control system of a motor vehicle. To control the drive slip and/or the vehicle dynamics, the control unit determines a variable which describes the speed of at least one driven wheel of the motor vehicle. Variables describing the respective wheel speeds for the remaining driven wheels of the motor vehicle, and a variable describing the output rpm of a transmission of the motor vehicle are available to the control unit.

Furthermore, the present invention relates to a memory element for a control unit of a traction control system or a vehicle-dynamics control system of a motor vehicle. The memory element is constructed in particular as a read-only memory, a random-access memory or a flash memory. Stored in the memory element is a computer program which is executable on a computing element, particularly on a microprocessor.

Finally, the invention also relates to a computer program which is executable on a computing element, particularly on a microprocessor.

Related Art

Methods and devices for determining a speed variable of at least one driven wheel of a motor vehicle are known in various specific embodiments from the related art.

Thus, for example, the German Patent 196 108 64 A1 describes a method and a device for determining a wheel speed. In that case, the rotational speed of at least one of two wheels of an axle is determined. To that end, a first variable representing the average rotational speed of the two wheels, and a second variable representing the vehicular speed are ascertained. The wheel speed is as a function of a comparison of the difference between a value derived from the first variable and a value derived from the second variable, to a threshold value. Upon falling below the threshold value, the rotational motion of the one wheel is determined at zero, and upon exceeding the threshold value, the rotational motion is determined at a value different from zero.

The ascertainment of the wheel speed known from DE 196 108 64 A1 has the disadvantage that a variable describing the vehicular speed is necessary. To be able to determine a precise wheel speed, a precise determination of the vehicular speed is required. This demands either very accurate estimation methods which determine the vehicular speed, for example, on the basis of the wheel speeds, or else special sensors for detecting the wheel speeds, which, however, require too much effort and are therefore costly. If the vehicular speed is determined as a function of the wheel speeds, only wheel speeds are available as initial quantities, based on which the rotational speed of at least one of two wheels of an axle is determined. Because of this, a systematic error can possibly develop, since a further variable which is independent of the wheel speeds does not go into the determination of the rotational speeds.

The German Patent 197 26 743 A1 describes a method and a device for automatically determining a differential ratio between a transmission of a motor vehicle and the wheels. In that case, a variable describing the speed of at least one wheel, and the output rpm of the transmission are determined. Furthermore, a driving-state variable describing the driving state of the motor vehicle is ascertained. If an essentially steady driving state exists, the variable describing the differential ratio is determined as a function of the variable describing the wheel speed, and the output rpm of the transmission.

The object of the present invention is to improve the ascertainment of a variable describing the wheel speed of at least one driven wheel of a motor vehicle. In particular, the intention is to provide a possibility of making a reliable variable describing the speed magnitude of the wheel available to a traction control system or a vehicle-dynamics control system of a motor vehicle, in spite of the failure of a speed sensor arranged at one of the wheels.

To achieve this objective, starting from the method of the type indicated at the outset, the present invention proposes that for the at least one driven wheel, the variable describing the speed be determined as a function of the variables which describe the respective wheel speeds of the remaining driven wheels, and as a function of the variable which describes the transmission output rpm.

Summary of the Invention

The driven wheels of a motor vehicle are generally fixedly coupled via a differential to the output end of a transmission. This holds true for the front-wheel drive (FWD) and a rear-wheel drive (RWD). In the case of an all-wheel drive (AWD), there is such a fixed coupling only when no slip-encumbered components, such as a viscous coupling, are

integrated into this part of the drive train. This fixed coupling exists in the case of all-wheel-drive vehicles with open differentials.

The variable describing the speed of at least one driven wheel can easily be determined according to the method of the present invention, given a fixed coupling of the driven wheels to the output end of the transmission. To that end, the known variables which describe the respective wheel speeds of the remaining driven wheels are utilized. In addition, the variable describing the transmission output rpm is utilized. As a rule, these variables are available in a control unit for the transmission or for a traction control system or a vehicle-dynamics control system and do not have to be determined separately.

The transmission output rpm is ascertainable with low expenditure and high accuracy. The determination is carried out, for example, by a speed sensor mounted at a suitable location on the transmission.

The method of the present invention can be used to check the performance reliability of wheel-speed sensors of the motor vehicle. For that purpose, the speed variable can be determined in succession for all wheels of the motor vehicle according to the method of the present invention and compared to the speed variable detected by the wheel-speed sensor to be checked.

With the aid of the method of the present invention, an equivalent quantity can be formed for a wheel speed or wheel rotational speed not directly available. For example, a directly determined variable is not available when a wheel-speed sensor is defective. Thus, using the method of the present invention, a reliable speed variable of the wheel can be made available in spite of the failure of a wheel-speed sensor. The system availability of a motor vehicle is thereby

increased, particularly in the event of a wheel-speed sensor malfunction. That is to say, the vehicle continues to be operable in spite of the failure or defect of a wheel-speed sensor. In particular, a reliable quantity describing the speed variable of the wheel can be made available to a traction control system or a vehicle-dynamics control system of a motor vehicle in spite of a malfunction of a wheel-speed sensor. In comparison to previously used traction control systems or vehicle-dynamics control systems, when using the method of the present invention, a system need no longer be switched into the passive state in response to a detected fault in a wheel-speed sensor. The system continues to be available and fully operative, in spite of such a fault or failure of the wheel-speed sensor,.

Such traction control systems or vehicle-dynamics control systems are known, for example, from the publication *"FDR - Die Fahrdynamikregelung von Bosch"* [VDC - The Vehicle Dynamics Control of Bosch] appearing in the Automobiltechnischen Zeitschrift (ATZ) 96, 1994, issue 11, on pp. 674 through 689. The yaw rate of a motor vehicle is controlled using a device described there. To control the yaw rate of the vehicle, the measured yaw rate is compared to a setpoint value for the yaw rate. Using this comparison, a system deviation of the yaw rate is determined, as a function of which driver-independent, wheel-individual braking interventions and/or engine interventions are carried out. Primarily by the driver-independent, wheel-individual braking interventions, a yaw moment is exerted on the vehicle, by which the actual yaw rate comes closer to. In the meantime, the described vehicle-dynamics control system is now also widely referred to as ESP (Electronic Stability Program). The contents of the publication *"FDR - Die Fahrdynamikregelung von Bosch"* are herewith intended to be included ibidem in the description and thus to be part of the description.

In summary, it can be said that: An equivalent quantity is

determined for the speed or the rotational speed of a motor-vehicle wheel having a failed wheel-speed sensor using the sensed rotational speed or speed of the remaining wheels and the output rpm of a transmission. The transmission is preferably an automatic transmission. However, the method of the present invention functions just as well with a manually shifted transmission having a manual or an automatic actuation.

According to one advantageous further development of the present invention, a variable specific to the wheel plane and describing the output speed is determined as a function of the transmission output rpm; and for the at least one driven wheel, the variable describing the speed is determined as a function of the variables which describe the respective wheel speeds of the remaining driven wheels, and as a function of the variable which describes the output speed.

According to a best mode of the invention, the variable specific to the wheel plane and describing the output speed is determined with the aid of the equation

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output}$$

R_{wheel} being the radius of the driven wheels and I_{Diff} being the effective differential ratio(s).

For a motor vehicle having all-wheel drive, the variable describing the speed for the at least one driven wheel is advantageously determined with the aid of the equation

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli}$$

For a motor vehicle having front-wheel drive or rear-wheel drive, the variable describing the speed for the at least one driven wheel is advantageously determined according to the equation

$$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel}$$

V_{wheel} being the wheel speed of the driven wheel whose wheel speed is not to be determined, that is to say, whose wheel-speed sensor is not defective.

As a further means for achieving the objective of the present invention, starting from the device of the type indicated at the outset, it is proposed that the device determine the variable describing the speed for the at least one driven wheel as a function of the variables which describe the respective wheel speeds of the remaining driven wheels, and as a function of the variable which describes the transmission output rpm.

According to one advantageous further development of the present invention, it is proposed that the device have means for carrying into effect the method according to the invention.

As a further means for achieving the objective of the present invention, starting from the control unit of the type indicated at the outset, it is proposed that the control unit determine the variable describing the speed for the at least one driven wheel as a function of the variables which describe the respective wheel speeds of the remaining driven wheels, and as a function of the variable which describes the transmission output rpm.

According to one advantageous further development of the present invention, it is proposed that means for carrying into effect the method according to the invention be implemented in the control unit.

Particularly significant is the implementation of the method according to the present invention in the form of a memory

element that is provided for a control unit of a traction control system or a vehicle-dynamics control system of a motor vehicle. In this context, a computer program that is executable on a computing element, in particular on a microprocessor, and is suitable for carrying out the method according to the present invention, is stored on the memory element. In this case, therefore, the invention is realized by way of a computer program stored on the memory element, so that this memory element provided with the computer program constitutes the invention in the same way as the method for whose accomplishment the computer program is suitable. In particular, an electrical storage medium, for example, a read-only memory, a random-access memory, or a flash memory, can be used as the memory element.

The invention also relates to a computer program that is suitable for carrying out the method according to the present invention when it is executed on a computing element, in particular on a microprocessor. In this context, it is particularly preferred if the computer program is stored on a memory element, in particular on a flash memory.

Brief Description of the Drawing

Additional features, possibilities for use, and advantages of the present invention come to light from the following description of exemplary embodiments of the present invention represented in the Drawing. In this context, all of the described or represented features, alone or in any combination, form the subject matter of the present invention, regardless of their combination in the patent claims or their antecedents, as well as regardless of their formulation and representation in the Specification and Drawing, respectively.

Figure 1 shows a block diagram of a device according to the present invention; and

Figure 2 shows a flow chart of the method according to the present invention.

Description of the Exemplary Embodiments

Figure 1 shows a drive train of a motor vehicle having four wheels 1, 2, 3, 4. The direction of travel of the motor vehicle is indicated by an arrow 20. The front wheels (front-wheel drive, FWD), the rear wheels (rear-wheel drive, RWD) or the front and rear wheels (all-wheel drive, AWD) can be driven in the motor vehicle. The driven wheels of the FWD and of the RWD are generally fixedly coupled via a differential to the output end of a transmission 5. In the case of AWD, there is a fixed coupling only when no slip-encumbered components, such as a viscous-friction coupling (so-called viscous coupling) are integrated into this part of the drive train. This fixed coupling exists in the case of all-wheel-drive vehicles with open differentials. As can be seen in Figure 1, the single-axle-driven motor vehicles, i.e. FWD and RWD motor vehicles, have two differentials 6, 7. All-wheel drive, i.e. AWD vehicles, have three differentials 6, 7, 8.

Both front wheels 1, 2 of the vehicle have wheel speeds V_{wheel1} and V_{wheel2}. Both rear wheels have wheels speeds V_{wheel3} and V_{wheel4}. The speeds of wheels 1, 2, 3, 4 are determined from rotational speeds n_{wheel1}, n_{wheel2}, n_{wheel3}, n_{wheel4} and from radius R_{wheel} of wheels 1, 2, 3, 4. Instead of radius R_{wheel}, it is also possible to utilize the diameter of wheels 1, 2, 3, 4. Rotational speeds n_{wheel1} n_{wheel2}, n_{wheel3} n_{wheel4} of wheels 1, 2, 3, 4 are detected by speed sensors 9, 10, 11, 12 which are arranged in the area of wheels 1, 2, 3, 4. Transmission 5 is an automatic transmission.

Transmission 5 is linked via a controller area network (CAN) bus 15, inter alia, to a control unit 14 of a vehicle-dynamics control system 14 that is also widely known as ESP (electronic

stability program). The design and the functioning method of an ESP is described in detail in the publication *"FDR - Die Fahrdynamikregelung von Bosch"*, ibidem, and is herewith intended to be included in the description and thus to be part of the description.

On condition that output rpm n_{output} of automatic transmission 5 is measured by an independent sensor 13 and all driven wheels are coupled in a slip-free manner to the output end of transmission 5, an equivalent quantity for a failed speed sensor 9, 10, 11 or 12 can be formed according to the method of the present invention. A prerequisite for this is that wheel 1, 2, 3 or 4 having the defective speed sensor is a wheel coupled to transmission 5, thus a driven wheel.

To carry out the method of the present invention, control unit 14 has a memory element 16 and a computing element, particularly a microprocessor 17. For example, memory element 16 is constructed as a flash memory. Stored on memory element 16 is a computer program which is executable on microprocessor 17 and is suitable for implementing the method of the present invention. To control the operating-dynamics stability of the motor vehicle, control unit 14 is supplied with input variable 18 which also include, inter alia, wheel speeds V_{wheel1}, V_{wheel2}, V_{wheel3}, V_{wheel4} and output rpm n_{output} of transmission 5. From these input variables 18, control unit 14 determines output quantities 19, for example, for controlling an internal combustion engine, a braking system (particularly an ABS braking system) or a steering system (particularly a steer-by-wire steering system) of the motor vehicle.

In the case of an AWD motor vehicle, the equivalent quantity describing speed $V_{wheelDef}$ of a wheel 1, 2, 3 or 4 having a defective wheel-speed sensor 9, 10, 11 or 12 is determined with the aid of the equation

$$V_{wheelDef} = 4 \cdot V_{output} - \sum_{i=1}^{3} V_{wheeli}$$

V_{output} being a variable specific to the wheel plane and describing the output speed of transmission 5, which is determined by the equation

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output}$$

V_{wheeli} is the rotational speed of the remaining driven wheels whose wheel-speed sensors are in working order. That is to say, output speed V_{output} is yielded as a function of output rpm n_{output} and a conversion factor for converting revolutions per minute (R/min) into meters per second (m/s). Output speed V_{output} corresponds to the average value of wheel speeds V_{wheeli} of the driven wheels.

In a motor vehicle having front-wheel drive or rear-wheel drive, the equivalent quantity is determined with the aid of the equation

$$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel}$$

V_{wheel} being the wheel speed of the other driven wheel whose wheel-speed sensor is in working order.

Depending on the type of drive of the motor vehicle, effective differential ratio I_{Diff} can be composed of the ratios of differentials 6, 7 and/or 8. In the case of a FWD, it is composed of the two differential ratios I_{DiffQ} of front differential 6 and $I_{Diffmiddle}$ of middle differential 8, and in the case of a RWD, it is composed of the two differential ratios $I_{DiffQ'}$ of rear differential 7 and $I_{Diffmiddle}$ of middle differential 8. In the case of an AWD, all differential ratios I_{DiffQ}, $I_{DiffQ'}$ und $I_{Diffmiddle}$ must be taken into account. In this context, differential ratio I_{Diff} is yielded as the product of the individual differential ratios. Allowance must possibly be

made for an effective off-road reduction.

In the event a wheel-speed sensor 9, 10, 11 or 12 is not in working order, an equivalent quantity which describes the speed of the wheel can be calculated for the wheel having the defective wheel-speed sensor using the method of the present invention. Thus, a shutdown of a complete vehicle-dynamics control system or a complete traction control system is no longer necessary. For example, it is conceivable to make an ABS function, i.e. a traction control system which is based solely on braking interventions, possible up to a specific vehicle speed with a defective wheel-speed sensor 9, 10, 11 or 12. The probability of the failure of the complete vehicle is therefore markedly reduced. This holds true in particular for off-road vehicles in which external wheel-speed sensors 9, 10, 11, 12 are subject to particularly high external stress during off-road travel. The shutdown behavior for the ABS case, i.e. the brake-slip control contained in the vehicle-dynamics control, can be developed more favorably, as well.

Figure 2 shows a flowchart of the method according to the present invention. The method begins in a functional block 30. In the following, it is assumed that the motor vehicle has a front-wheel drive (FWD), and the intention is to determine an equivalent quantity describing the speed of wheel 2. To that end, in a functional block 31, first of all a variable specific to the wheel plane and describing output speed V_{output} of transmission 5 is determined. Output speed variable V_{output} is determined as a function of transmission output rpm n_{output} according to the following equation

$$V_{output} = \frac{\pi}{30} \cdot \frac{R_{wheel}}{I_{Diff}} \cdot n_{output}$$

The equivalent quantity describing speed $V_{wheelDef} = V_{wheel2}$ of wheel 2 is subsequently determined in a functional block 32 according to the following equation

$$V_{wheelDef} = 2 \cdot V_{output} - V_{wheel}$$

In this context, V_{wheel} is the speed of wheel 1 having speed sensor 9 in working order. In a functional block 33, the method of the present invention is then brought to an end.

Wheel-speed variable $V_{wheelDef}$, determined with the aid of the method according to the present invention, is compared to wheel speed V_{wheel2} which was detected by speed sensor 10 of wheel 2. If the deviations of the two wheel speeds exceed a specifiable threshold value, a malfunction of speed sensor 10 is assumed. Naturally, wheel-speed variable $V_{wheelDef}$ utilized with the method of the present invention can also be utilized as equivalent quantity for wheel speed V_{wheel2} of wheel 2 in the event speed sensor 10 is defective.